Video Games:

A Human Factors Guide

to Visual Display Design and Instructional System Design

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Abstract

Electronic video games have many of the same technological and psychological characteristics that are found in military computer-based systems. For this reason, the video game is both a fascinating object of study and a valuable experimental apparatus. The results of two on-going research programs, both of which employ video games as experimental stimuli, are presented here.

The first research program seeks to identify and exploit the characteristics of video games in the design of game-based training devices. The second program is designed to explore the effects of electronic video display characteristics on perceptual judgments. The empirical results of these two programs are shown to have practical application in training device design and visual display design.

Video Games and Training Device Design

Although games in general have been employed as learning vehicles, the especially compelling characteristics of electronic video games have not been fully explored for possible exploitation in the design of computer-based training systems. In fact there is little empirical evidence regarding the perceived or salient qualities of these new electronic video games. Accordingly, the following experiment was designed to determine those dimensions along which electronic video games are perceived to vary.

Method

Twenty right-handed male first-year college students served as subjects. The experimental stimuli consisted of ten commercial electronic video games and an "ideal" video game. The "ideal" video game was defined to subjects as their notion of the best or ideal video game, whether imaginary or real.

The twenty subjects were asked to make pairwise comparisons of the similarity of the eleven video game stimuli. Judgments were made with the use of rating scale in which 0 was defined as "these two games are not at all similar" and 100 was defined as "these two games are exactly alike." All judgments were made in a commercial video game arcade closed to the public.

Results and Discussion

The game similarity data were subjected to a multidimensional scaling (MDS) analysis. Given judgments or measures of similarity, MDS provides a spatial representation of stimuli that reveals dimensions relevant to an observer. For example, if two stimuli are judged to have a similar quality, they are placed near each other in a multidimensional space; stimuli judged to be dissimilar are located distant from each other.

A three-dimensional MDS solution was deemed appropriate after examining the squared correlations (RSQ) associated with solutions for different dimensional spaces. The RSQ is a measure of the proportion of variance of monotonically transformed data accounted for by the MDS model. The RSQ's for a one-dimensional (1D) solution through a five-dimensional (5D) solution for the game similarity data are: 1D-0.225; 2D-0.294; 3D-0.314; 4D-0.289; 5D-0.292. Here, the RSQ decreases at the 4D solution and clearly indicates that no more than three dimensions should be considered for interpretation. This decrease in RSQ reflects the subjects' insensitivity to differentiating the games on more than three dimensions.

The first dimension, called "Destructiveness", orders games according to the type of response stragegy necessary for successful play. One end of this dimension is anchored by games which involve the destruction of alien objects by the proactive manipulation of a "mother-ship" capable of firing bullets/lasers/etc. The other end of this dimension is anchored by games which require reactive, avoidance strategies (e.g., avoidance of ghosts, alligators, or barrels). Thus, the first dimension ranges from proactive destruction to reactive avoidance.

The "ideal" game was positioned near the center of the "Destructiveness" dimension. An examination of the raw similarity scores indicated that subjects fell into two groups with respect to the characteristics of an ideal game on this dimension. Specifically, destruction of opponents is an ideal characteristic of video games for half the subjects; the other half prefer games which require avoidance strategies.

The second dimension, called "Dimensionality", locates games according to the number of physical dimensions (on the video screen) in which the player can maneuver. On one end of this dimension, the player's "piece" can be effectively moved in only one dimension (left to right on the visual screen). In the games near the center of this dimension, player movement is two-dimensional (left-right and up-down). Finally, the games on the opposite end provide the visual appearance of movement in three-dimensional space.

It is noteworthy that most subjects found simulated three-dimensional games quite difficult to master and that, at the same time, the "ideal" game is placed between the two- and three-dimensional game groupings. This phenomenon is consistent with so-called "optimal-level" theories of motivation which postulate that moderate levels of cognitive/physical complexity are maximally arousing. Hence, games which allow movement in only one dimension may be too "simple" and three-dimensional games too "complex", in so far as these games are presently configured. Two-dimensional games (or something "between" two- and three-dimensional games) may be maximally motivating. As experience or familiarity with these games increases, one would expect game

preference to shift toward the more "complex" or "difficult" ones.

The third dimension revealed by MDS, "Graphic Quality," orders games by their degree of color vibrancy and resolution. At one end of the continuum, games are characterized by a relative lack of color and by relatively low graphic resolution. At the other end, games are characterized by vibrant colors, fine detail, and high graphic resolution. On this continuum the "ideal" game is located at the graphic quality extreme, suggesting that subjects prefer games with high quality graphics.

Applications and Future Research

These results have several applications in the design of computer-based video training systems. For example, the findings suggest that video game-based lessons will be more compelling if they are designed with high quality graphic displays and simulated movement in two or three dimensions. A second application derives from the finding that some subjects prefer avoidance to destructive behaviors (i.e., reactive to proactive behaviors). Implied here is the need for a fit in personnel training between this cognitive preference and the type of task required for successful completion of a game-based training lesson. Consider, for example, a mathematics lesson embedded in a game where correct answers result in the avoidance of falling barrels. Such a lesson might be most compelling (ideal) for those subjects who prefer games which require reactive, avoidance behaviors. Conversely, subjects who prefer proactive game behaviors would find the same mathematics lesson most compelling if correct answers result in the destruction of alien objects.

Finally, the present results may be recast in an individual differences framework. That is to say, the psychological predispositin toward destructive (or avoidance) game behaviors may be a valid instrument for classifying personnel and predicting future success. This classification would be of special use when, say, the task to be learned is inherently destructive (e.g., shooting enemy aircraft) and difficult to embed in a game-based training device that required avoidance behaviors. In such a situation, subjects who prefer avoidance game behaviors would not be selected for training. Hence, future research should consider the role of personality variables as a moderator of game-based training success.

Video Games and Visual Display Design

The modern military environment is increasingly characterized by the electronic exchange and display of large amounts of information. It is important to determine whether and understand how the characteristics of these visual information displays affect perceptual judgments and consequent decisions.

The effect of visual display characteristics on the perception of time has received little attention. However, the accurate perception of time is of increased importance in job environments where decisions are time-critical and where information is received via electronic visual displays. These implications are best highlighted by means of a hypothetical example:

The commander of an armor battalion sits inside a mobile command post several miles behind the forward edge of the battle area. The battalion commander is receiving information about the battle on a computer screen which simulates the terrain and troop strength of his forces and the enemy forces; the screen is 4 inches on its diagonal. He finds that his position is under heavy conventional weapons attack and that the enemy is close to overrunning his defenses. Division command informs him that reinforcements will not arrive for another 30 minutes. He is further instructed to hold his position no matter what the cost and he is authorized to use a theater nuclear weapon if the defensive line is broken.

Will the commander misjudge the passage of time because of the characteristics of the visual display? One characteristic of interest is the scale of the information presented on the visual display. Accordingly, the purpose of the following experiment was to determine whether the perception of time is affected by the scale of the visual display.

Method

The subjects were 72 first-year college students, half of whom were female. The independent variable for this experiment was the screen size of a television monitor which was connected to a commercially available video game. There were three levels of screen size: a 5 inch (on the diagonal) screen, a 12 inch screen, and a 23 inch screen. The subjects were randomly assigned to one of the three screen size levels with the restriction that half the subjects assigned to each screen size were female.

The subjects were asked to play a computer video game which displayed a simulated combat situation on the television screen. The object of the game was to shoot and destroy moving enemy targets by using a joystick to aim and fire a gun.

Each subject was given 55 seconds of playing time. At the end of this interval, the subject was asked to estimate (in seconds) as accurately as possible the length of time the simulated combat situation had lasted. These time estimates served as the dependent variable for the experiment.

Results and Discussion

A 3 x 2 analysis of variance was performed on the time estimates. There were three levels of screen size: 5 inch, 12 inch, and 23 inch. There were two levels of the second variable, sex of the subject.

The effect of screen size on time estimates was found to be significant ($p = .005$). The mean time estimate for the 5-inch screen was 120.5 seconds; the 12-inch screen mean time estimate was 76.1 seconds; and the mean estimate for the 23-inch screen was 67.9 seconds. In other words, the perception of elapsed time for a given clock interval (55 seconds) increased as screen size decreased.

The effect of sex on time estimates was significant at $p = .06$, and females tended to give longer time estimates at each level of screen size. The interaction of screen size and sex did not approach significance.

Applications and Future Research

The preliminary results of this research clearly suggest that the scale or size of a visual display affects the perception of time. The most pronounced "distortion" of time perception was found with a 5-inch visual display -- this is typical of the size of visual monitors found in aircraft, ships, and tanks.

Because this research is in its early stage, the scope and generality of the findings for the design of visual displays is not certain. Nevertheless, the results reported here have potentially dramatic significance for environments in which information is visually displayed and in which decisions are time-critical.

Summary

The popularity of electronic video games is of interest because these games have qualities similar to those found in various military computer-based systems. Moreover, the commercial video game arcade is an *in vivo* proving ground for the "fittest" of electronic games -- hence these games may provide design guidelines for system developers.

The exploratory and preliminary results discussed above clearly demonstrate that the video game is both a valuable object of study and a useful experimental apparatus. The results also serve to define the direction of video game research now underway.

Footnote

The views, opinions, and/or findings contained in this report are those of the author and should not be construed as an official Department of the Army or Department of Defense position, policy, or decision, unless so designated by other official documentation.

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